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(71) Applicant (*for all designated States except US*): **VESUVIUS CRUCIBLE COMPANY** [US/US]; Foulk Road 103, Suite 200, Wilmington, DE 19803 (US).

(72) Inventors; and
(75) Inventors/Applicants (*for US only*): **DI DOMENICO, Giampiero** [IT/BE]; 132 rue de Crespin, B-7350 Hensies (BE). **FLORIO, Fabrizio** [IT/BE]; 253 rue de Dour, B-7300 Boussu (BE).

(74) Agent: **DEBLED, Thierry**; Vesuvius Group S.A., Intellectual Property Department, Rue de Douvrain 17, B-7011 Ghlin (BE).

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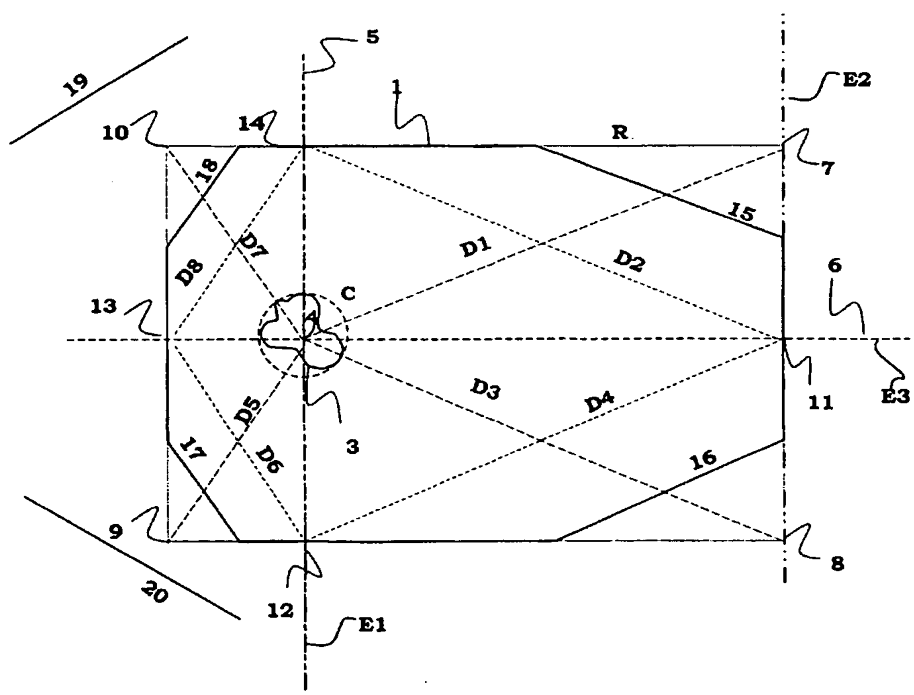
[Continued on next page]

(54) Title: PROCESS FOR REPAIRING A CRACK RESISTANT VALVE PLATE



(57) Abstract: The invention relates to a process for repairing refractory plate (1), having a pouring hole (3), circumscribed by a circle C of center (4), at least a portion of the edges (15, 16, 17, 18) of the plate (1) are angularly oriented so as to focus the clamping forces optimally in the throttling area and around the pouring hole.

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Declarations under Rule 4.17:

— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii)) for the following designations AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, OM, PH, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TN, TR, TT, TZ, UA, UG, UZ, VN, YU, ZA, ZM, ZW, ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG)*

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Process for repairing a crack resistant valve plate

Description

[0001] This invention generally relates to a process for repairing worn valve plates for use in slide gate valves for controlling a flow of molten metal, and specifically for a valve plate that is resistant to cracks caused from thermomechanical stresses.

[0002] Slide gate valves are commonly used to control a flow of molten metal in steel making and other metallurgical processes. Such valves generally comprise a support frame, an upper stationary valve plate having an orifice in registry with a tundish or ladle nozzle for conducting a flow of molten metal, and a throttle plate likewise having a metal conducting orifice that is slidably movable under the stationary valve plate. In slide gate valves used in conjunction with continuous casting molds, a lower stationary valve plate is provided beneath the movable throttle plate which likewise has a flow conducting orifice that is substantially aligned with the orifice of the upper stationary plate. The rate of flow of molten metal is dependent upon the degree of overlap of the orifice of the slidably movable throttle plate with the orifice of the upper stationary plate. The movable throttle plate is usually longer than the stationary throttle plate in order to give it the capacity of throttling the flow of molten metal from both the front and back edges of its own orifice, as well as the ability to shut off the flow altogether by bringing its orifice completely outside of any overlap with the orifices of the stationary plate. Typically, the throttle plate is slidably manipulated between the stationary plates by means of a hydraulic linkage.

[0003] The throttle plate and the stationary plate are mounted in respectively a lower indentation and an upper indentation, each of these plates resting in an indentation through a surface that becomes its support surface and cooperating with the other plate through a surface that becomes its sliding or working surface.

[0004] Both the throttle plate and the stationary plates of such slide gate valves are formed from heat and erosion resistance refractory materials, such as aluminum oxide, alumina-carbon, zirconium oxide. However, despite the heat and erosion resistance of such refractory materials, the severe thermomechanical stresses that they are subjected to ultimately causes some degree of cracking to occur. For example, in steel making, each valve plate is subjected to temperatures of approximately 1600°C in the area immediately surrounding its flow-conducting orifice, while its exterior edges are experiencing only ambient temperature. The resulting large thermal gradient creates large amounts of thermomechanical stress as the area of each plate immediately surrounding its orifice expands at a substantially greater rate than the balance of the plate. These stresses cause cracks to form which radiate outwardly from the orifice of the plate. If nothing is done to contain the spread of these cracks, they can extend all the way to the outer edges of the plate, causing it to break.

[0005] To prevent the spreading of such cracks and the consequent breakage of the valve plates, various solutions have been developed in the prior art. In a first attempt,

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improved clamping mechanisms have been designed. The purpose of these mechanisms is to apply sufficient pressure around the perimeter of the plate so that cracks emanating from the orifice do not spread to the edges of the plate. One such mechanism comprises a frame having screw-operated wedges which engage corners of the plate that have been truncated in an angle that is complementary to the angle of the wedges. Such a system is disclosed in the document DE-C2-3,522,134. While such frame and wedge-type clamping mechanisms constitute an advance, the inventors have noted some shortcomings with this design that prevent it from achieving its full, crack-retarding potential. Generally, the clamping forces are not uniformly focused where the maximum amount of cracking occurs, i.e., in the vicinity of the orifice where the greatest amount of thermomechanical stresses are present. Moreover, the applicants have observed that, generally, the angular orientation of the truncated corners in such plates does not optimally prevent the spreading of cracks, as previously thought. Such non-optimality results from the fact that crack formation is not uniformly distributed 360° around the orifice, but instead is biased along the longitudinal center line of all valve plates whether stationary or movable. Such an asymmetrical distribution of cracks around the plate orifices is believed to occur as a result of the longitudinal sliding action of the throttle plate across the faces of the stationary plates.

[0006] The USP 5,626,164 discloses a crack resistant valve plate; the shape of said plate being designed to prevent the formation and spreading of cracks therein. This plate has an axis, and an orifice for conducting molten metal that is positioned along said axis, and truncated corners for focusing a clamping force toward said axis in the vicinity of said orifice, wherein each of said truncated corners is orthogonal to a line extending between a tangent point to said orifice, across said axis, and through an intersection of lines drawn parallel to converging plate edges that are spaced from said edges a distance equal to one-half of a width of said orifice.

[0007] In the document WO-A1-98/05451, there is disclosed a variant of this solution wherein the angles between the lateral faces of the plate are defined so as to extend the life-time of the plate.

[0008] While the USP 5,626,164 solution constitute already a markedly clear advance over the previously known solution, applicants have tried to still optimize the plate shape.

[0009] Clearly, there is a need for a valve plate whose shape optimally focus the clamping forces in the most crack-prone areas of the plate in order to maximally retard the lengthening of any such cracks. Ideally, the corners should have a length sufficient to avoid the production of unwanted localized mechanical stresses in the corners.

[0010] The International Patent application WO01/41956 discloses a crack resistant valve plate assembly for use in a slide gate valve that overcomes or at least ameliorates all of the disadvantages associated with the prior art or that at least equals the performance

of the plate disclosed in USP 5,626,164.

[0011] This document relates thus to a refractory plate for a slide gate valve which may be circumscribed by an elongated rectangle R having two sides parallel to the direction of its elongation. The rectangle R has a longitudinal axis which is defined as its longest symmetry axis and that will coincide with the preferential sliding trajectory of the plate. It is however to be clearly understood that this concept of preferential sliding trajectory is an intrinsic characteristic of the plate according to this document and that this plate may be slid in a gate valve according to a direction which is not the optimal or preferential one. The plate has an orifice – the pouring hole - for conducting molten metal. Most often said orifice is circular, more generally, it is circumscribed by a circle C of diameter Φ.

[0012] For construction purpose, the rectangle R is divided into four quadrants by two perpendicular lines intersecting at the center of the circle C, one of these lines extending in the middle between the parallel sides of the rectangle R. Each quadrant has intersecting diagonals: diagonals D1, D3, D5, D7 joining the center of the circle C to the corners of the rectangle R and diagonals D2, D4, D6 and D8 joining adjacent intersections of the perpendicular lines intersecting at the center of the circle C with the sides of the rectangle R.

[0013] The pouring hole may be centrally located in the plate, but most often, it is offset along the longitudinal axis so that throttling may be effected on a longer area. The pouring hole may also be slightly offset along an axis perpendicular to the longitudinal axis.

[0014] The plate has angularly oriented edges – figuring the truncated corners of the rectangle R – for focusing clamping forces toward the vicinity of the orifice and toward the throttling area to prevent the formation and spreading of cracks therein.

[0015] According to WO01/41956, at least a portion of the edges are defined as follows:

- the edges farest from the pouring hole (thus, closest to the throttling area) deviate at maximum 5° from the directions of the diagonals which does not intersect the respective corner and
- the edges closest to the pouring hole (thus farest from the throttling area) deviate at maximum 5° from one of the following direction
    - (i) - the direction perpendicular to the diagonal intersecting the respective corner;
    - (ii) - the direction of the other respective quadrant;
    - (iii) - a direction intermediate between the directions (i) and (ii).

[0016] Applicants have indeed determined that such a plate shape focus optimally the clamping force to two different areas of the plate. On the one hand, the throttling area is kept in compression, preventing thus the apparition of cracks in that region and on the other hand, the perimeter of the pouring hole is also kept in compression, preventing thus the spreading of cracks radiating from the pouring hole.

[0017] Applicants have observed that the newly designed plate is extremely advantageous. Firstly, far less cracks are observed. Secondly, even if they still occur, the cracks do not spread up to the plate edges, so that air ingression is markedly reduced. And thirdly, when the plate according to this European application is used in combination with an appropriate clamping device, the cracks, if any, only occur in acceptable area. I.e., they do not occur in the throttling area, neither do they occur directly in the area between the pouring hole and the closest edges.

[0018] A further advantage of this plate is that since very few cracks have been observed, the plate can be easily and quickly repaired after having been used. This is why the present invention concerns a process for repairing the used plates disclosed in the WO01/41956.

[0019] The plate may be symmetrical with respect to its longitudinal axis, but in the preferred embodiment, the plate is not symmetrical with respect to the longitudinal axis.

[0020] Thanks to this asymmetry, the plate may only be mounted in one position in the upper indentation and in one position in the lower indentation so that the support surface of the plate becomes its sliding or working surface when the plate passes from one position to the other in case recycling of the plates is desirable.

[0021] The plate may have only four edges defined as above, but in order to avoid sharp angles, it may have more edges. In such a case, the supplemental edges may (or not) be parallel and/or perpendicular to the longitudinal axis.

[0022] It must be understood that it is not mandatory that the plate be polygonal. On the contrary, in case a clamping band is used around the plate, such clamping band can apply localized mechanical stresses - which could turn into cracks - onto the vertex defined by adjacent edges. Therefore, it is advantageous that the corner be rounded.

[0023] In the preferred embodiment, only a portions of the edges satisfy the above definition. More preferably, the balance of the edges are comprised of curves joining the said edges portions and most preferably of transition radius of the said edges.

[0024] It must also be understood that in the scope of the present invention a "plate" means also a plate of an assembly (fixed or removable) such as a monobloc nozzle plate, a monobloc inner nozzle plate, a monobloc tube plate, etc.

[0025] The present invention concerns thus a process for repairing a worn refractory plate for a slide gate valve, which may be circumscribed by an elongated rectangle R having two sides parallel to the direction of its elongation and having a pouring hole positioned eccentrically in the middle between the parallel sides of the rectangle R and circumscribed by a circle C, the rectangle R being divided into four quadrants by two perpendicular lines intersecting at the center of the circle C, one of these lines extending in the middle between the parallel sides of the rectangle R, each quadrant having intersecting diagonals: D1, D2 and D3, D4 and D5, D6 and D7, D8, respectively, wherein

the corners of the rectangle R are cut away and replaced by inclined edges and the direction of at least a portion of those edges which are farest from the pouring hole deviate at maximum 5° from the direction of the diagonal which does not intersect the respective corner; and

- the direction of the edges which are the closest to the pouring hole deviate at maximum 5° from one of the following directions

(i) - the direction perpendicular to the diagonals intersecting the respective corner;

(ii) - the direction of the other diagonal of the respective quadrant;

(iii) - a direction intermediate between the directions (i) and (ii).

[0026] Any suitable repairing process could be used. It should be understood that it is precisely by virtue of its exceptional crack-resistance that these plates can be easily, quickly and efficiently repaired.

[0027] Generally, the repairing process comprises a step of patching the cracks with mortar, preferably with a mortar capable of resisting the molten steel such as a phosphatic mortar, for example REFRACOL 620 PL 45.

[0028] If needed, it might be necessary to grind true the surface of the plate before patching the cracks. For example to remove the remaining steel from the surface of the plate. Any conventional technique, such as grinding, sanding, water jet blasting, etc. can be used.

[0029] Once the cracks patched, the excess of mortar is removed and the plate is allowed to dry. Drying can be carried out at ambient temperature for at least 4 hours, preferably at least 8 hours or in an oven for example at 120°C for 1 hour.

[0030] The plate can then be cured. This curing step might be performed at 350-450°C during one hour. In a variant, curing can also occur during use of the repaired plate when it is subjected to high servicing temperatures.

[0031] In a particular embodiment, the plate is preheated for example at about 80-120°C, so that the mortar penetrates deep into the cracks and sets quickly.

[0032] In another embodiment, the mortar comprises a hardener so that, even at ambient temperature, it sets up quickly.

[0033] In case the pouring orifice is damaged, it can also be repaired. Generally, a tubular article (such as a pipe, a rod or a mandrel) having a diameter substantially similar to the original diameter of the pouring orifice is engaged into the pouring orifice. Mortar (generally the same as the one used for the cracks) is patched around the tubular object, dried and eventually cured.

[0034] In a variant, it is also possible to drill a hole (preferably coaxial with the original pouring orifice and having a diameter preferably at least 50% greater than the original diameter of the pouring orifice), placing and mortaring an insert into the newly drilled

hole. The insert is preferably made of a material at least as resistant as the original material of the plate. It may be convenient to provide the external walls of the insert with protrusions or holes so that the mortar and the insert are interpenetrated. It is also possible to use stepped insert shaped as two (or more) superimposed coaxial tubes having the same inner diameter but different external diameters.

[0035] FIGS. 1 and 2 are top plan views of plates of WO-A1-01/41956.

[0036] With reference now to Fig. 1, wherein like numbers designate like components throughout the figures, this document discloses a valve plate **1** for use in a slide gate valve of the type used to regulate a flow of molten steel or other metal from a tundish to a mold or from a ladle to a tundish.

[0037] The plate **1** has an orifice **3** for pouring the molten metal stream. Said pouring hole **3** is circumscribed by a circle C of center **4**. Fig. 1 illustrates a plate with a non circular pouring hole and Fig. 2 shows a plate with a pouring hole **3** corresponding to the circle C.

[0038] Rectangle R is visible on Figs. 1 and 2. Rectangle R circumscribes plate **1** and has its longest sides parallel to the sliding trajectory of the plate in the slide gate valve. For construction purpose, it is necessary to draw two perpendicular lines **5** and **6** which cross at the center **4** of the circle C and which are parallel to the short and long sides of the rectangle R. These lines define thus four quadrants of the rectangle R. Each quadrant has intersecting diagonals: D1, D3, D5 and D7 joining the center **4** of the circle C to the four corners (**7**, **8**, **9**, **10**) of the rectangle R and D2, D4, D6 and D8 joining adjacent intersections (**11**, **12**, **13**, **14**) of the lines **5** and **6** with the sides of the rectangle R.

[0039] The edges of the plate specially designed to focus the clamping forces in the throttling area, i.e. the edges **15** and **16** which are the farest from the pouring hole **3**, thus closest to the throttling area, have at least a portion (against which the clamping force will be applied) that is parallel to the diagonal D2 or D4 of the quadrant containing said edge.

[0040] On both Figs. 1 and 2, at least a portion of the edge **15** is parallel to the diagonal D2 and at least a portion of the edge **16** is parallel to the diagonal D4. On Fig. 1, the entire edges **15** and **16** are parallel to the diagonals D2 and D4 while on Fig. 2, only a portion of the edges **15** and **16** is parallel to the diagonals D2 and D4.

[0041] The edges of the plate which are specifically designed to focus the clamping forces around the pouring hole **3**, i.e. the edges **17** and **18** which are the closest from the pouring hole **3** may be shaped perpendicular to the diagonals D5 or D7 of the quadrant containing said edge or, in other words, parallel to a direction **19** or **20** defined as a perpendicular to the diagonals D5 or D7. This embodiment is illustrated on both edges **17** and **18** of Fig. 2 which are respectively perpendicular to diagonals D5 and D7.

[0042] Alternatively, these edges **17** and **18** may be shaped parallel to the diagonals D6 or D8 of the quadrant containing them as is illustrated on edges **17** and **18** of Fig. 1 which are parallel to diagonals D6 and D8.

[0043] In another variant, the edges **17** and **18** may be oriented in a direction comprised between the two above defined directions.

[0044] The edges **15, 16, 17** and **18** may contact each other, defining thus a tetragonal plate **1**, defined by the joint diagonals D2, D4, D6 and D8. Obviously, to avoid mechanical stresses, it is preferred to avoid such tip-shaped corners. Therefore, preferably, the edges **15, 16, 17** and **18** do not contact directly. They may be separated by straight lines, preferably parallel to the sides of the rectangle as illustrated on Fig. 1.

[0045] Even more preferably, they are separated by transition curves.

[0046] On Fig. 2, edges **15** and **16** and edges **17** and **18** are joined by transition radii **21** and **22**.

[0047] The essential parameter is the orientation of the edges **15, 16, 17** and **18**, which will determine the way they focus the clamping forces to avoid the cracks. Their position with respect to the pouring hole **3**, i.e. the position of the edges **15, 16, 17** and **18** along the respective diagonals D1, D3, D5 and D7 is less important for that criteria. However, it is preferable that the edges **15, 16, 17** and **18** are not too long to avoid the mechanical stresses due to the tip-shaped corners, nor too short for efficiently focusing the clamping forces where it is necessary.

[0048] Therefore, the edges which are closest to the throttling area, i.e. edges **15** and **16** (or their projections) should preferably cut the short side of the rectangle R in a region comprised respectively between 1/8 and 3/8 and between 5/8 and 7/8 of the length of the short side of the rectangle R.

[0049] This requirement is less important on the other side of the plate (i.e. the side where the edges are closest to the pouring hole), so that edges **17** and **18** (or their projection) should preferably cut the short side of the rectangle R in a region comprised between 1/10 and 9/10 of the length of the short side of the rectangle R.

[0050] The document WO01/41956 describes a method to determine whether or not a plate is designed according to its teachings.

Claims

1. Process for repairing a worn refractory plate (1) for a slide gate valve, circumscribed by an elongated rectangle R having two sides parallel to the direction of its elongation and having a pouring hole (3) positioned eccentrically in the middle between the parallel sides of the rectangle R and circumscribed by a circle C of center (4), the rectangle R being divided into four quadrants by two perpendicular lines (5, 6) intersecting at the center (4) of the circle C, one (6) of these lines (5, 6) extending in the middle between the parallel sides of the rectangle R, each quadrant having intersecting diagonals D1, D2, and D3, D4 and D5, D6 and D7, D8, respectively wherein the corners (7-10) of the rectangle R are cut away and replaced by inclined edges (15-18) and at least a portion of those edges (15,16) which are farest from the pouring hole (3) deviates at maximum 5° from the direction of the diagonal which does not intersect the respective corner, **characterized in that** the direction of the edges (17, 18) which are closest to the pouring hole (3) deviate at maximum 5° from one of the following directions:
   (i) the direction perpendicular to the diagonal intersecting the respective corner,
   (ii) the direction of the other diagonal of the respective quadrant,
   (iii) a direction intermediate between the directions (i) and (ii).

2. Process according to claim 1, comprising a step of patching the cracks with mortar.

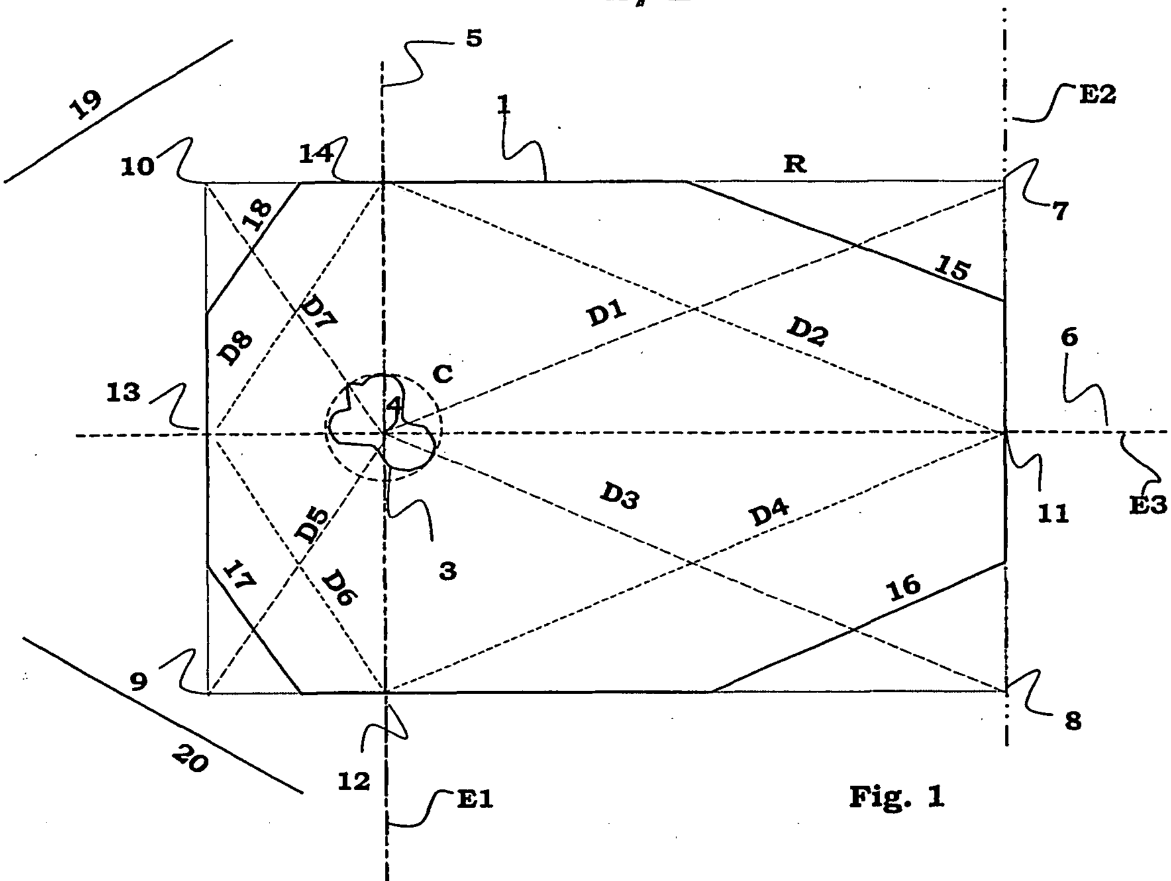
3. Process according to any of claims 1 or 2, comprising the following steps:
   a) drilling of a hole substantially coaxial with the original pouring orifice and having a diameter at least 50% greater than the original pouring orifice.
   b) placing an insert into the drilled hole
   c) patching mortar between the insert and the walls of the drilled hole.

4. Process according to claims 2 or 3, **characterized in that** the mortar is a phosphatic mortar.

5. Process according to any of claims 2 to 4, comprising a step of drying the patched plate.

6. Process according to any of claims 2 to 5; comprising a step of curing the patched plate.

7. Plate obtainable by a process according to any one of claims 1 to 6.



5
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D6
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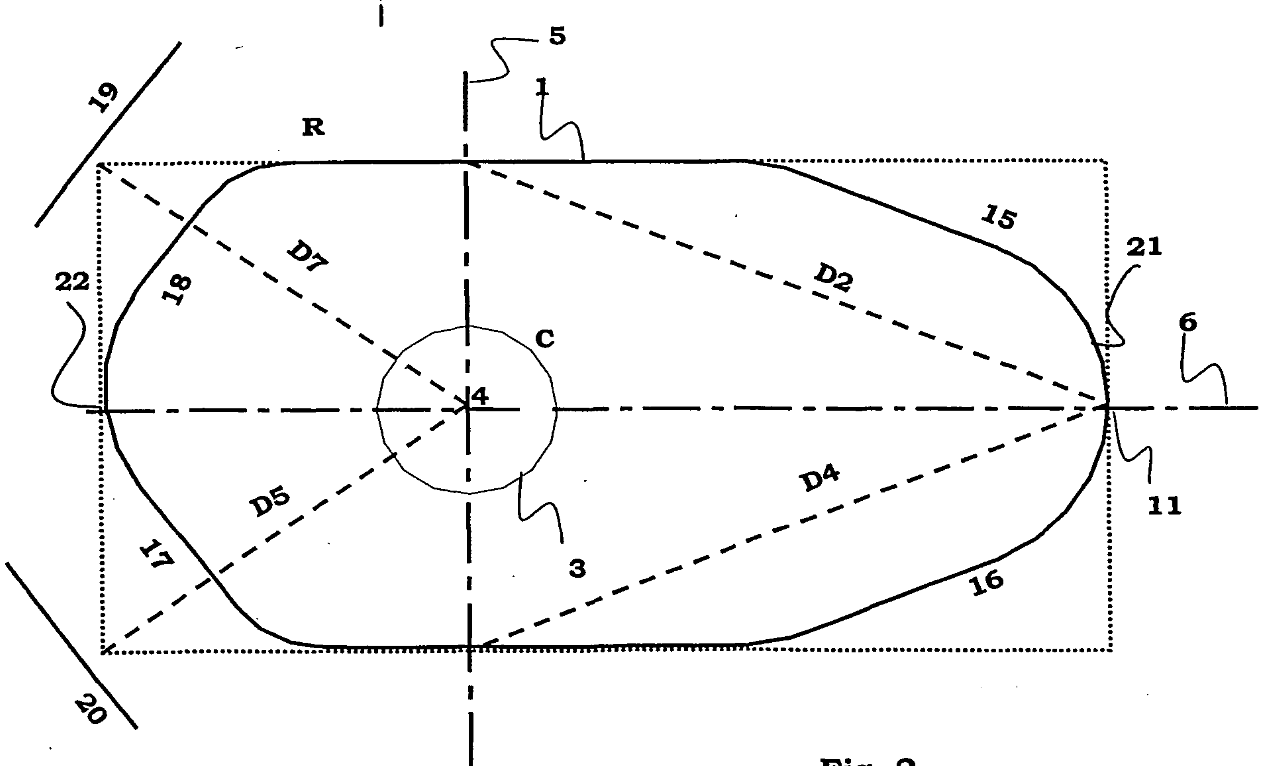
Fig. 1



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D2
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D4
D5
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Fig. 2

INTERNATIONAL SEARCH REPORT

Inter nal Application No
PCT/BE 02/00025

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 B22D41/30 B22D41/28

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 B22D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
P,X	WO 01 41956 A (BOISDEQUIN VINCENT ;ROTHFUSS HANS (DE); VESUVIUS CRUCIBLE CO (US)) 14 June 2001 (2001-06-14) claim 1; figures 1,2 ---	1
A	US 5 626 164 A (RICHARD FRANCOIS N ET AL) 6 May 1997 (1997-05-06) cited in the application claims 1-7; figures 2,6-9 ---	1
A	DE 35 22 134 A (FLO CON SYST) 9 January 1986 (1986-01-09) cited in the application claims 1,2,4-6; figures 2,7 ---	1
	-/--	

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

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Date of the actual completion of the international search	Date of mailing of the international search report
22 May 2002	24/06/2002

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Mailliard, A

Inter[ ]nal Application No
PCT/BE 02/00025

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
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